First application of mass measurements with the Rare-RI ring reveals the solar r-process abundance trend at $A = 122$ and $A = 123$[†]

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The rapid neutron capture process (r-process) is responsible for synthesizing about half of the elements beyond iron up to bismuth, as well as all of the thorium and uranium. Masses of the neutron-rich nuclides are essential input parameters for the r-process simulation. However, most of the nuclides involved in the r-process can not be produced in the laboratory. Usually, the masses predicted by the theoretical mass models are used. Not only does measuring the mass of exotic nuclei provide dependable experimental data for r-process calculations, but it also plays a crucial role in improving mass models.

The Rare-RI Ring at RIBF is a newly commissioned cyclotron-like storage ring mass spectrometer.1) We performed the mass measurement experiment for the exotic nuclei on the southwest of the ^{132}Sn with R3. In this experiment, five $N = 77$ isotones, ^{127}Sn, ^{126}In, ^{125}Cd, ^{124}Ag, ^{123}Pd, were produced by the in-flight fission of ^{238}U beam, selected by the BigRIPS and finally injected into the R3. Details of the experiment can be found in the previous report.2) Masses of ^{126}In, ^{125}Cd, and ^{123}Pd were measured whereby the mass uncertainty of ^{123}Pd was improved.

We investigate the impact of the new mass value of ^{123}Pd on the solar r-process abundances in the r-process by employing the Portable Routines for Integrated nucleoSynthesis Modeling reaction network.3) Reaction network calculations of 20 trajectories with a specific entropy 40 k_B/baryon, expansion timescale τ = 20 ms and varying electron fraction Y_e from 0.15 to 0.35 in steps of 0.01 are performed. The $A = 122$ to $A = 123$ abundance ratio for each trajectory with the new mass result is calculated and compared with the baseline model in which the mass value of the ^{123}Pd is taken from FRDM2012,4) as shown in Fig. 1. We find that the abundance ratio of each trajectory in the baseline model is smaller than the solar ratio, making it impossible to reproduce the observed feature with any combination of trajectories. However, when the newly measured ^{123}Pd mass was used, the ratio is sufficiently varied across the range of trajectories. This variability makes it possible to use suitable linear combinations of trajectories to reproduce the observed ratio. The increase in the abundance ratio is attributed to changes in calculated nuclear properties resulting from the newly measured ^{123}Pd mass. The neutron capture cross section for ^{122}Pd decreases by a factor of 2.6 and for ^{123}Pd increases by a factor of 2.2, while the probability for the β-delayed neutron emission of ^{123}Rh increases by 14% with the updated mass. This results in the material pileup along the $A = 122$ isobar relative to the baseline.

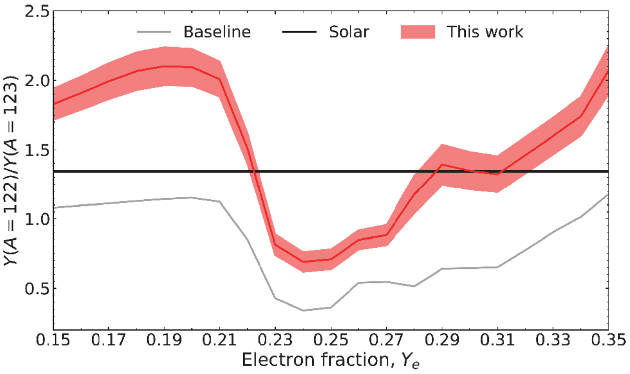

Fig. 1. Ratio of the $A = 122$ to $A = 123$ isotopic abundances as a function of electron fraction for the baseline model (gray line) and if our new mass measurement (red line) and its uncertainty (red band) are included. The horizontal black line indicates the value of the same ratio in the solar r-process residuals of Ref. 5).

References

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